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SYSTEM OF SYSTEMS OPERATIONAL ANALYSIS WITHIN A COMMON OPERATIONAL CONTEXT

MORS 2005 Conference
David A. Flanigan
JHU/APL
22 June 2005



Objective

- To develop a process to analyze the value of a system of systems (SoS) effort towards mission accomplishment
 - This example will focus on a surface warfare (SUW) scenario in the littorals for describing the process and example analysis
- Provide a methodology to utilize multiple tools towards generating a solution to the given problem set



Agenda

- Problem Space
- SoS Analysis Process
 - Scenario setup
 - Tie-in with other tools
 - Execution & analysis
- SUW Example
- Conclusion



Problem Space

- Within an SUW scenario, red platforms will attempt to arrive unhindered to their objective (typically a blue high value location)
- The blue objective is to successfully intercept these red platforms either prior to start or during the red transit
 - This problem looks at the transit phase, not at pre-emptive strike efforts
 - Blue surveillance platforms and interceptors will be stationed along the expected threat axis to detect and track the target, while directing blue interceptors towards the target
 - Blue stationing may depend on defended area requirements, red stand-off ranges, available locations, etc.



Legacy Solution Space

- The legacy solution space will require multiple blue surveillance platforms to perform detection and tracking of the target, directing blue interceptors towards the target
- The legacy architecture allows independent detection and tracking efforts, with no fused tactical picture capability

The overall picture is only as good as the best ONE surveillance platform capability!

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Future Solution Space

- Explore the utility of a system of systems approach
- Each blue surveillance platform contributes its detection/tracking of the red threat, combining these tracks into one shared picture
- The hypothesis is that a few networked sensors are better than many independent sensors
- This presentation will develop a methodology for quantifying the added value of the future solution space

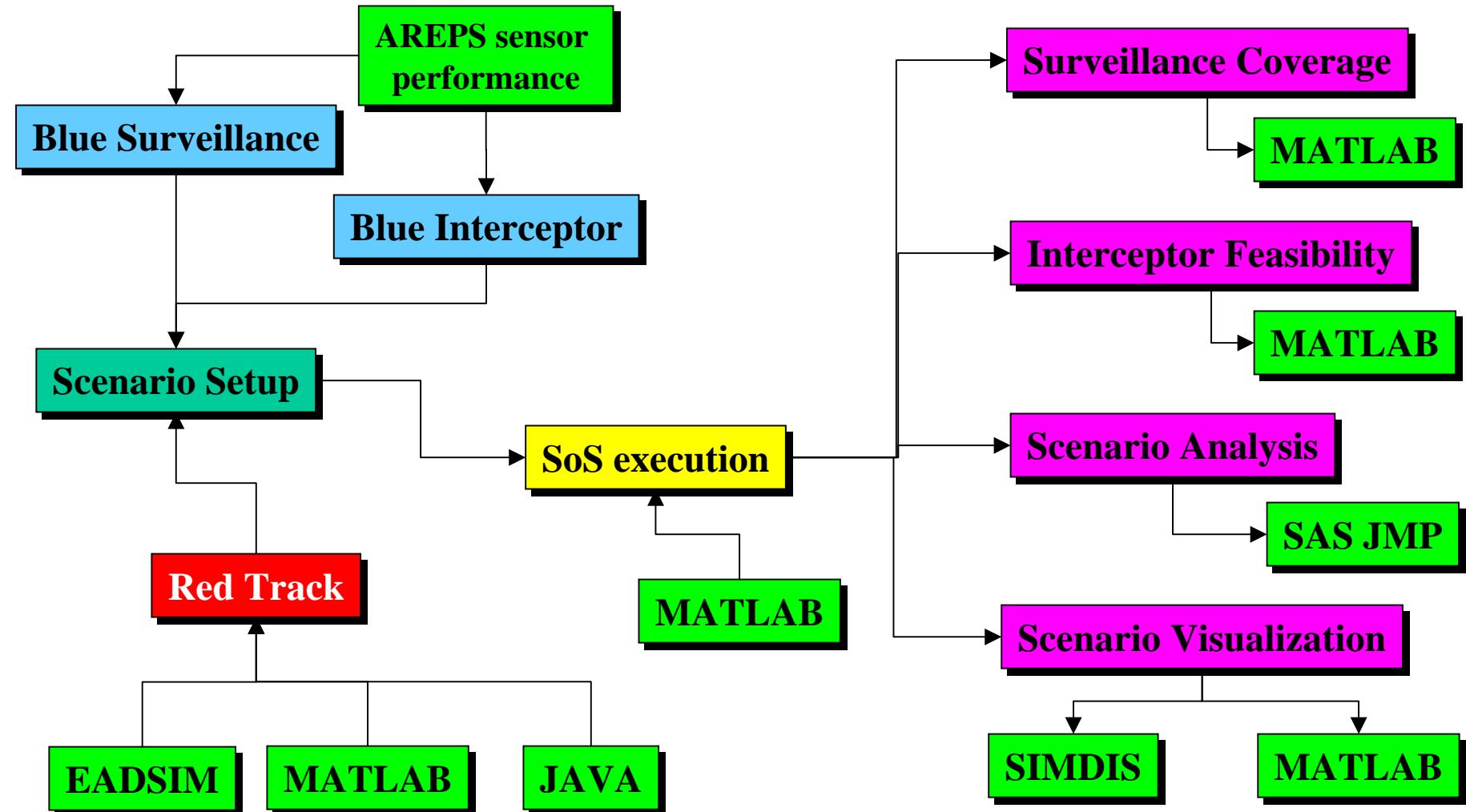


SoS Development Process

- Construct a framework of multiple applications to contribute towards a SoS representation
 - SoS architecture
 - Scenario setup
 - Platform / sensor representations
 - Scenario execution
 - Assessment functions (highlighted in the example)
 - Surveillance coverage
 - Interceptor feasibility
 - Significant factors in the scenario
 - Hypothesis investigation



SoS Architecture





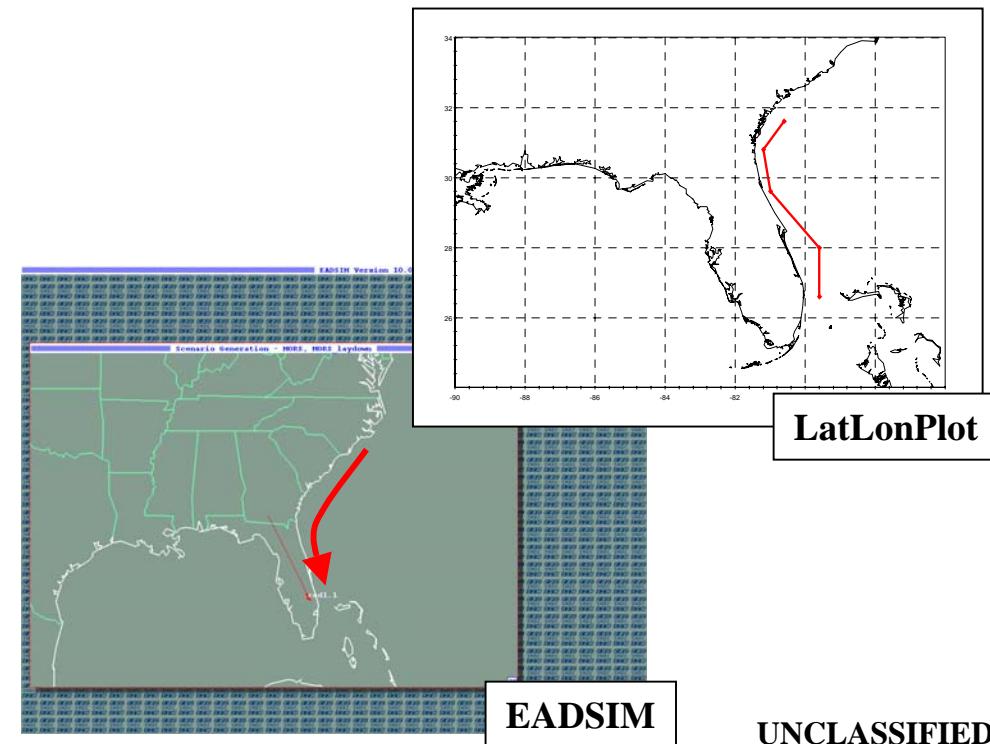
Scenario Setup

- Start of the problem
- Define red path
- Define blue surveillance and interceptor attributes
- Define the desired response
 - Ex: tradeoffs between speed and sensor performance, first-order assessment of asset placement, etc.



Red Platform Attributes

- Develop a path for the red platform to transit during the scenario
- Construct a path that allows an opportunity to exercise the SoS
 - A variety of tools may be used
 - EADSIM, LatLonPlot, maps, etc.
 - Starting and ending points
 - Speed of platform



EADSIM

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Blue Surveillance Attributes

- Develop a matrix of what the blue surveillance platform is capable of:
 - Number of surveillance assets
 - Location during the scenario
 - Capabilities of sensor
 - Range
 - Scan rate
 - Probability of detection

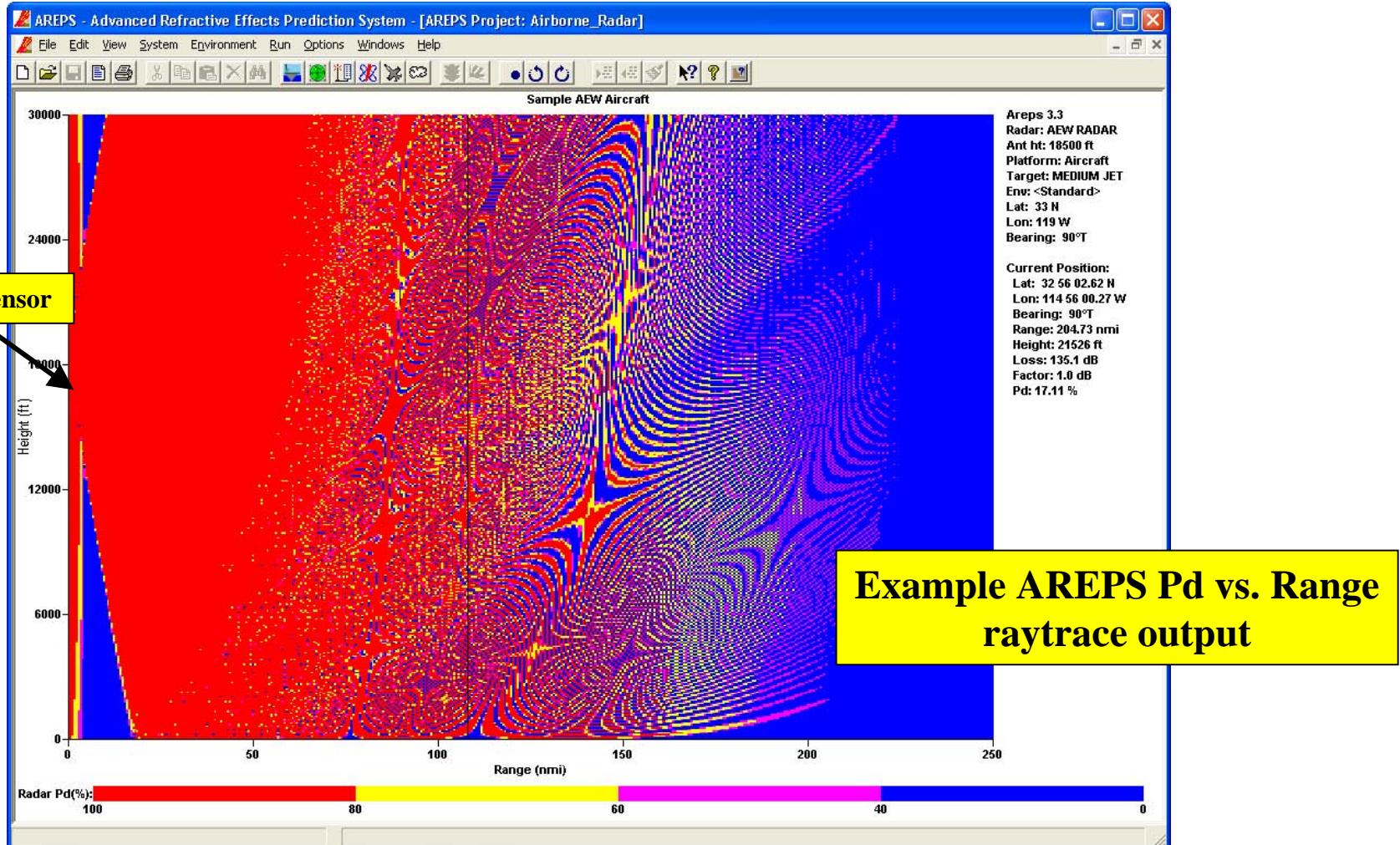


Sensor Information from AREPS

- The use of the Advanced Refractive Effects Prediction System (AREPS) produced by SPAWAR provides the effects of specific radar parameters to build the characteristic AEW or interceptor radar
- Provides Probability of Detection vs. Range plots
- Import into MATLAB to curve-fit for later use



Sensor Information from AREPS



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Sensor Information from AREPS

AREPS - Advanced Refractive Effects Prediction System - [Radar Editor [AEW RADAR]]

File Edit View System Environment Run Options Windows Help

Classification: NONE Level 1 Level 2 Level 3

Radar Calculations/Type: Simple pulsed radar Integrated - Incoherent Integrated - Coherent CW or other radar

Optional information: 0°N Latitude (Deg), 0°E Longitude (Deg), 10. Antenna height (ft) (MSL), Unknown Function, None Associated weapon

Vertical Antenna Pattern: Pattern angle (Deg), Pattern factor (dbi)

Your identification label: SinXX

Frequency (MHz): 400.

Peak power (kW): 1000.

Pulse length (μs): 2.

Compressed pulse length (μs): 0.

Receiver noise figure (dB): 5.

Assumed system loss (dB): 3.

Maximum instrumented range (km): 200.

Pulse rate (Hz): 200.

Free-space range (1 sqm target) (km): 0.

Probability of false alarm: 1.0E-08

Antenna type: Horizontal

Polarization: 8. Hits per scan

Antenna gain (dbi): 25.

Antenna scan rate (rpm): 12.

Horizontal beam width (Deg): 3.

Vertical beam width (Deg): 10.

Antenna elevation angle (Deg): 0.

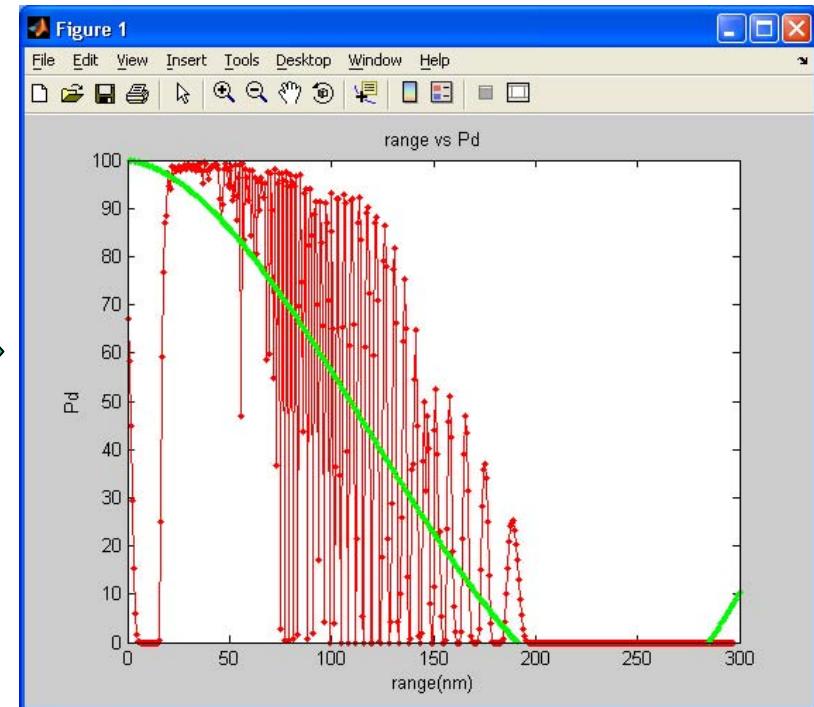
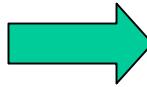
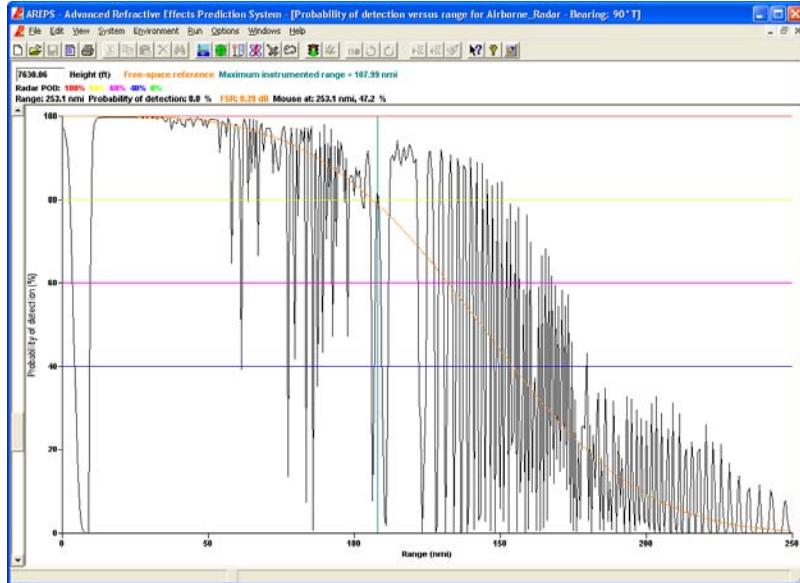
Build the sensor capability

A screenshot of the AREPS software interface. The window title is "AREPS - Advanced Refractive Effects Prediction System - [Radar Editor [AEW RADAR]]". The menu bar includes File, Edit, View, System, Environment, Run, Options, Windows, and Help. The toolbar contains various icons for file operations and system functions. On the left, there are two columns of dropdown menus: "Classification" (NONE, Level 1, Level 2, Level 3) and "Radar Calculations/Type" (Simple pulsed radar, Integrated - Incoherent, Integrated - Coherent, CW or other radar). Below these are "Optional information" fields for latitude, longitude, antenna height, function, and associated weapon. To the right is a "Vertical Antenna Pattern" table with columns for "Pattern angle (Deg)" and "Pattern factor (dbi)". The main area contains a list of radar parameters with their values: identification label (SinXX), frequency (400. MHz), peak power (1000. kW), pulse length (2. μs), compressed pulse length (0. μs), receiver noise figure (5. dB), assumed system loss (3. dB), maximum instrumented range (200. km), pulse rate (200. Hz), free-space range (0. km), and probability of false alarm (1.0E-08). The "Antenna type" is set to "Horizontal" and "Polarization" is "8. Hits per scan". Below these are fields for antenna gain (25. dbi), scan rate (12. rpm), horizontal beam width (3. Deg), vertical beam width (10. Deg), and antenna elevation angle (0. Deg). A red box highlights the first seven parameters (identification label, frequency, peak power, pulse length, compressed pulse length, receiver noise figure, assumed system loss). A blue callout box with the text "Build the sensor capability" points to the bottom of this red box. A black arrow points from the text "Build the sensor capability" to the bottom of the red box.

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Probability of Detection vs. Range data from AREPS



Import data into MATLAB after curve-fitting

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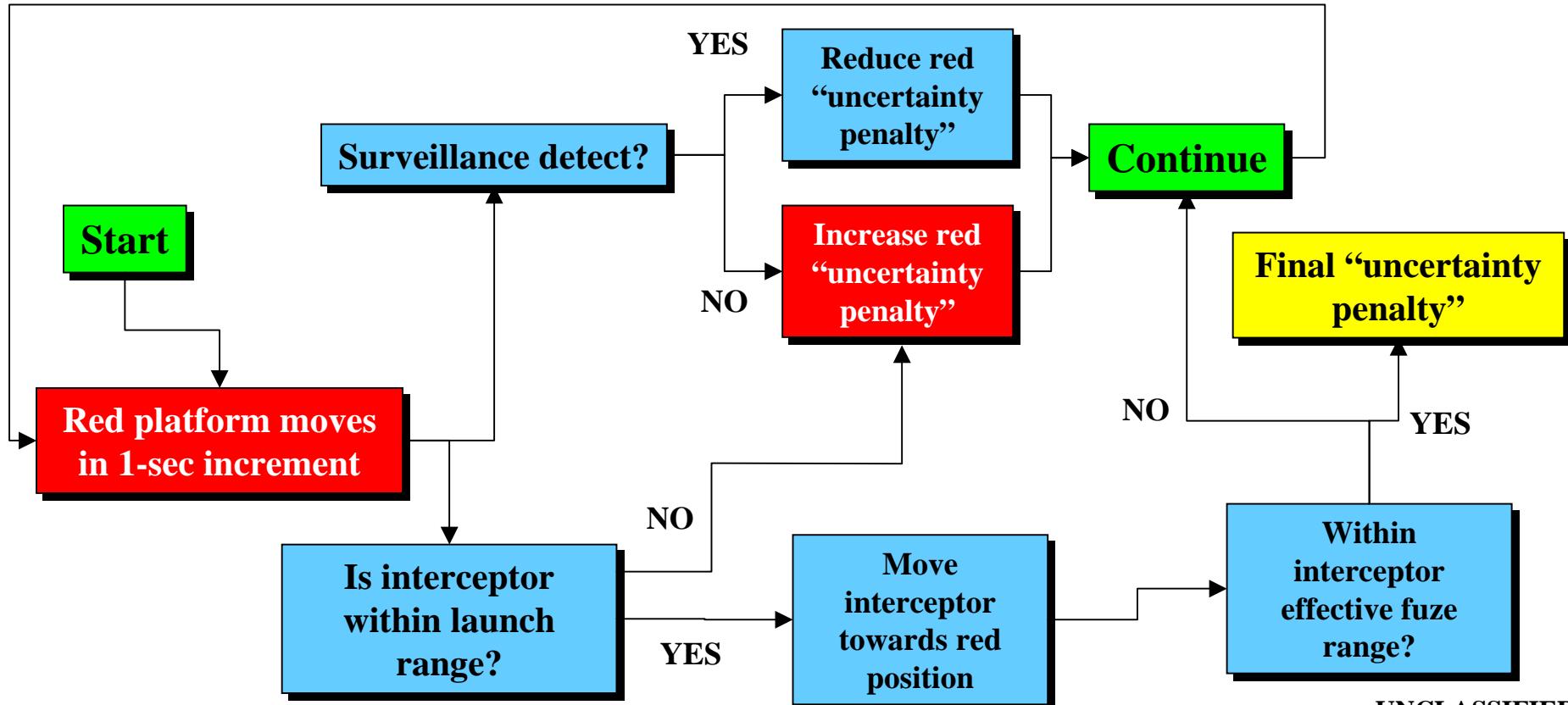
Blue Interceptor Attributes

- Develop a matrix of what the blue interceptor is capable of:
 - Number of interceptor assets
 - Location during the scenario
 - Capabilities of interceptor sensor
 - Maximum effective range
 - Scan rate
 - Probability of detection
 - Effective (fuze) range
 - Range of initiation of interceptor



Scenario Execution Example

- MATLAB-based script to accept scenario setup files
- Time-stepped simulation



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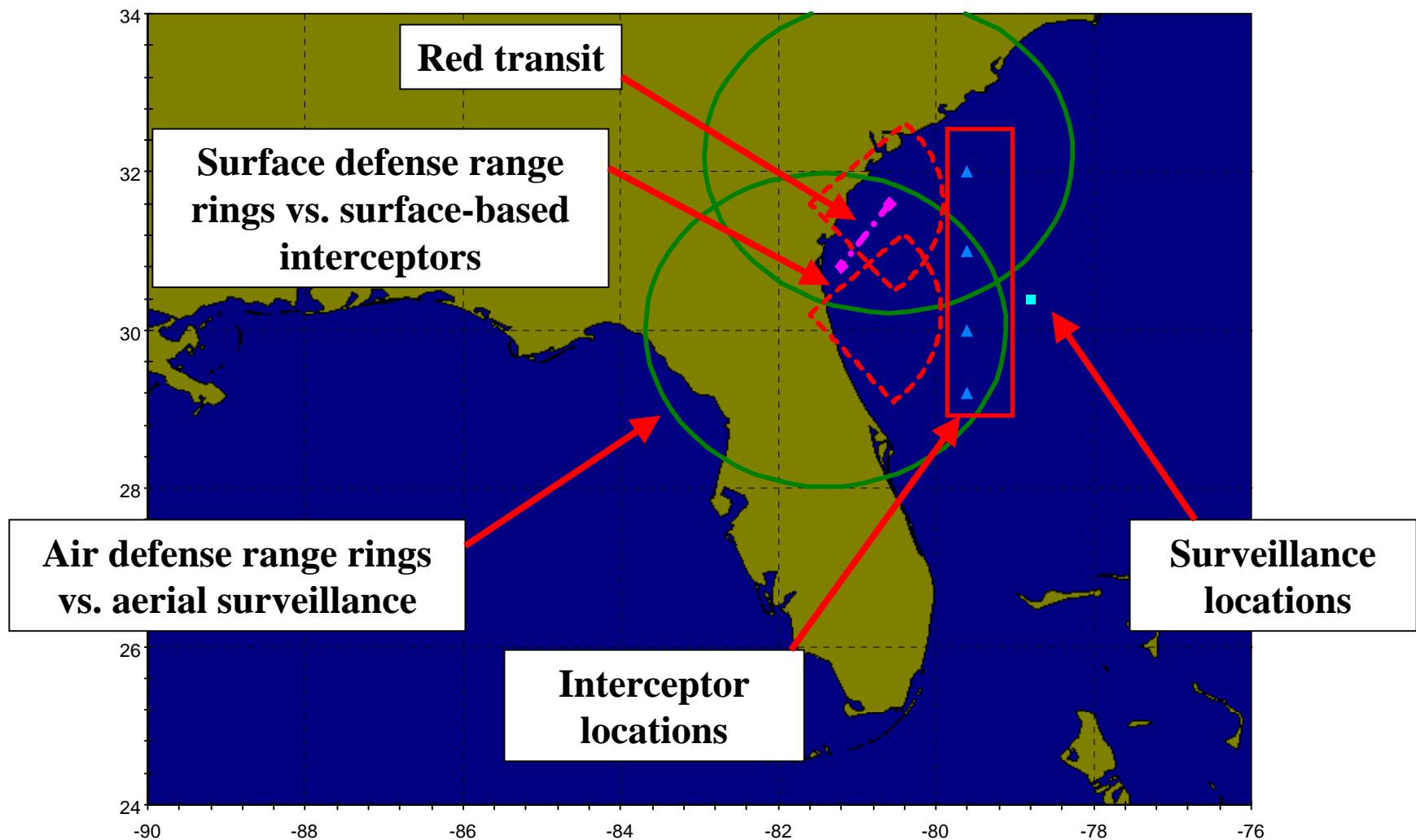


Surface Warfare (SUW) Application

- Apply similar methodology towards a surface warfare (SUW) mission area problem
- Example: red surface platforms are transiting underneath the umbrella of red air and surface defenses, posing a problem of surveillance and interceptor placement for successful red intercept.
- Determine the desired response
 - “Final uncertainty penalty” based on a single surveillance platform and multiple interceptor positions
- Given the following options
 - Surveillance sensor performance and scan rates
 - Interceptor seeker performance and scan rates
- Determine what combination of variables are most significant to the problem
- Investigate hypothesis of multiple sensors to add value to the situation



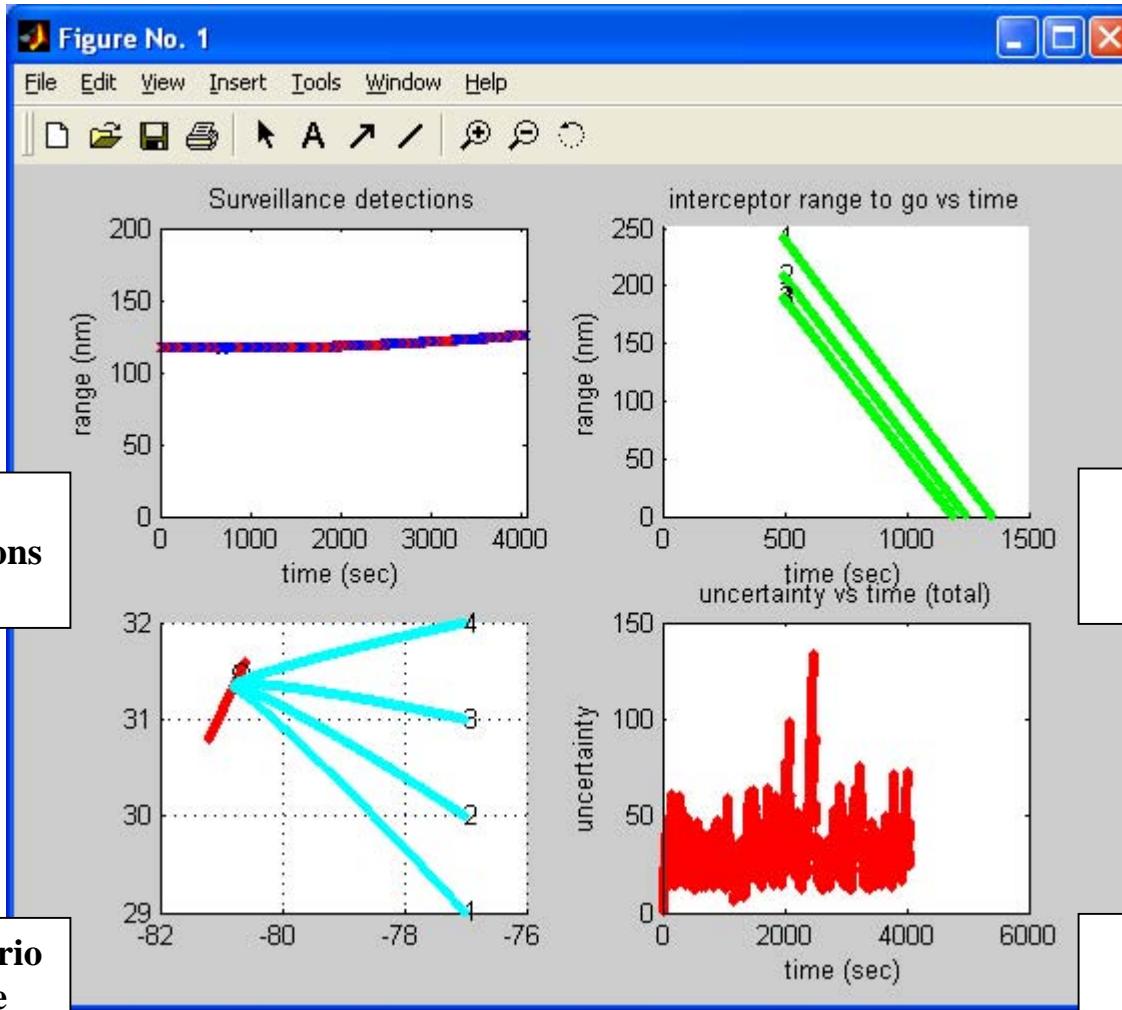
SUW Application



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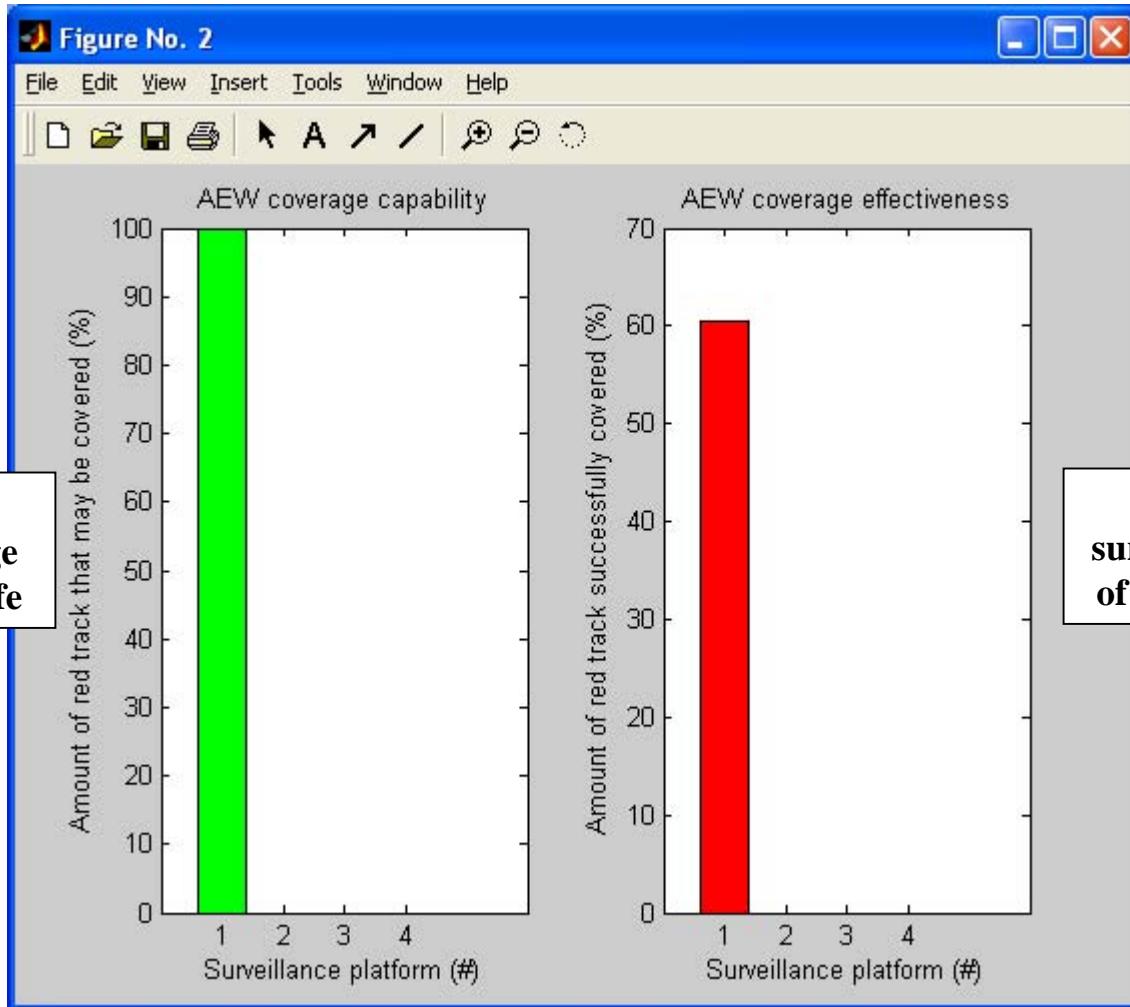
Example Output (Surveillance & Interceptor)



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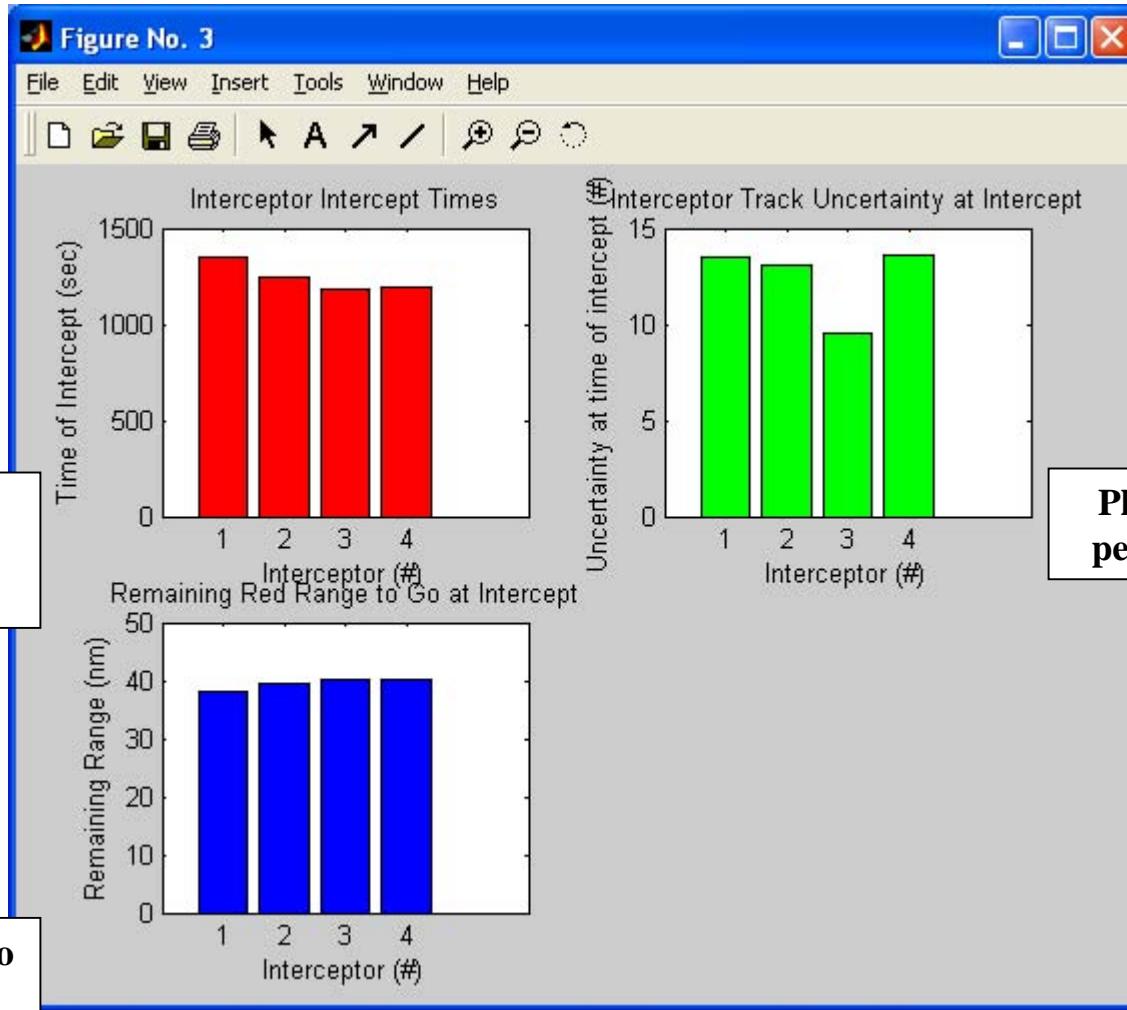
Example Output (Surveillance)



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Example Output (Interceptor)



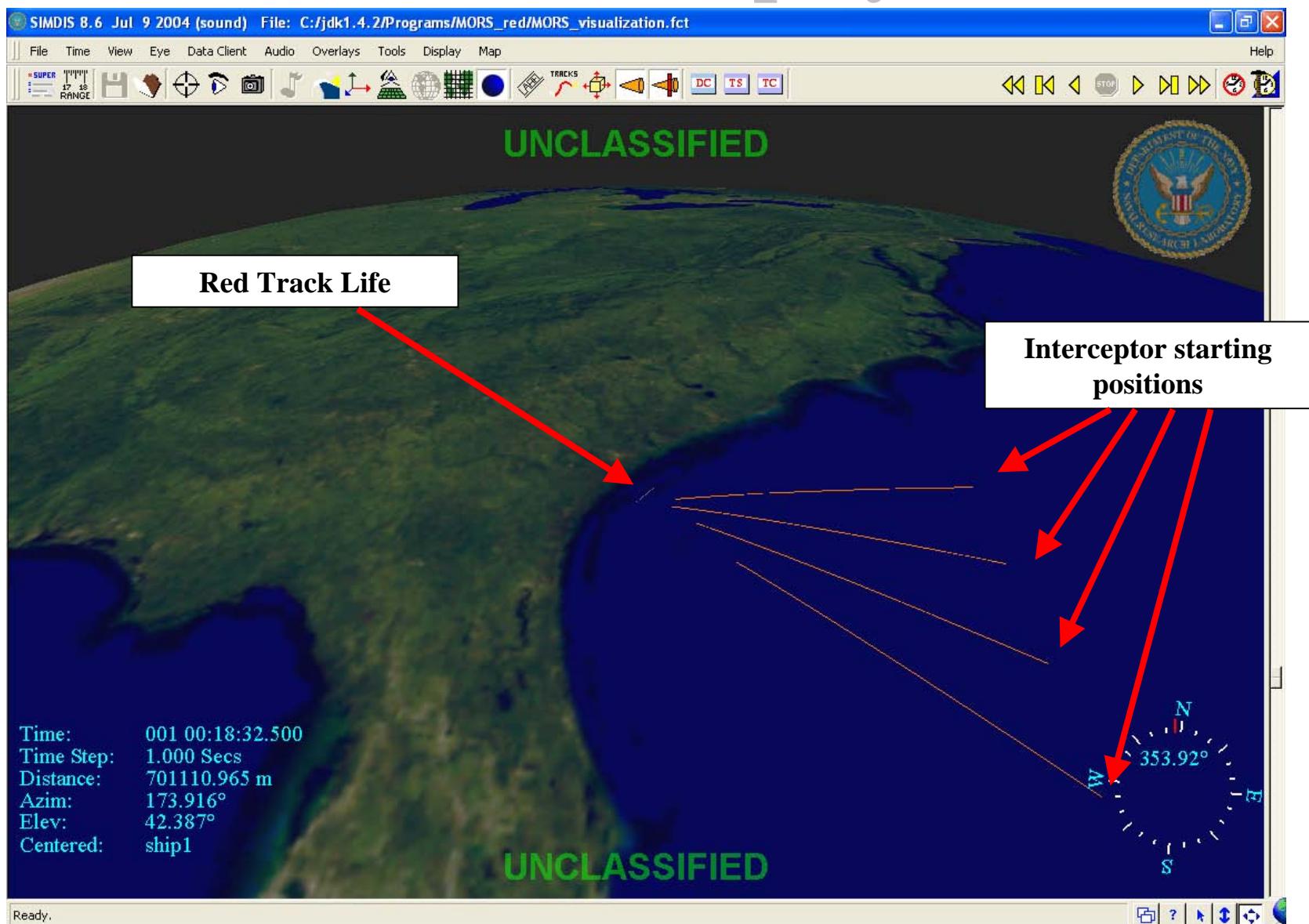
Plot of interceptor intercept during scenario

Plot of red track left to go at intercept

Plot of “uncertainty penalty” at intercept



SIMDIS Display



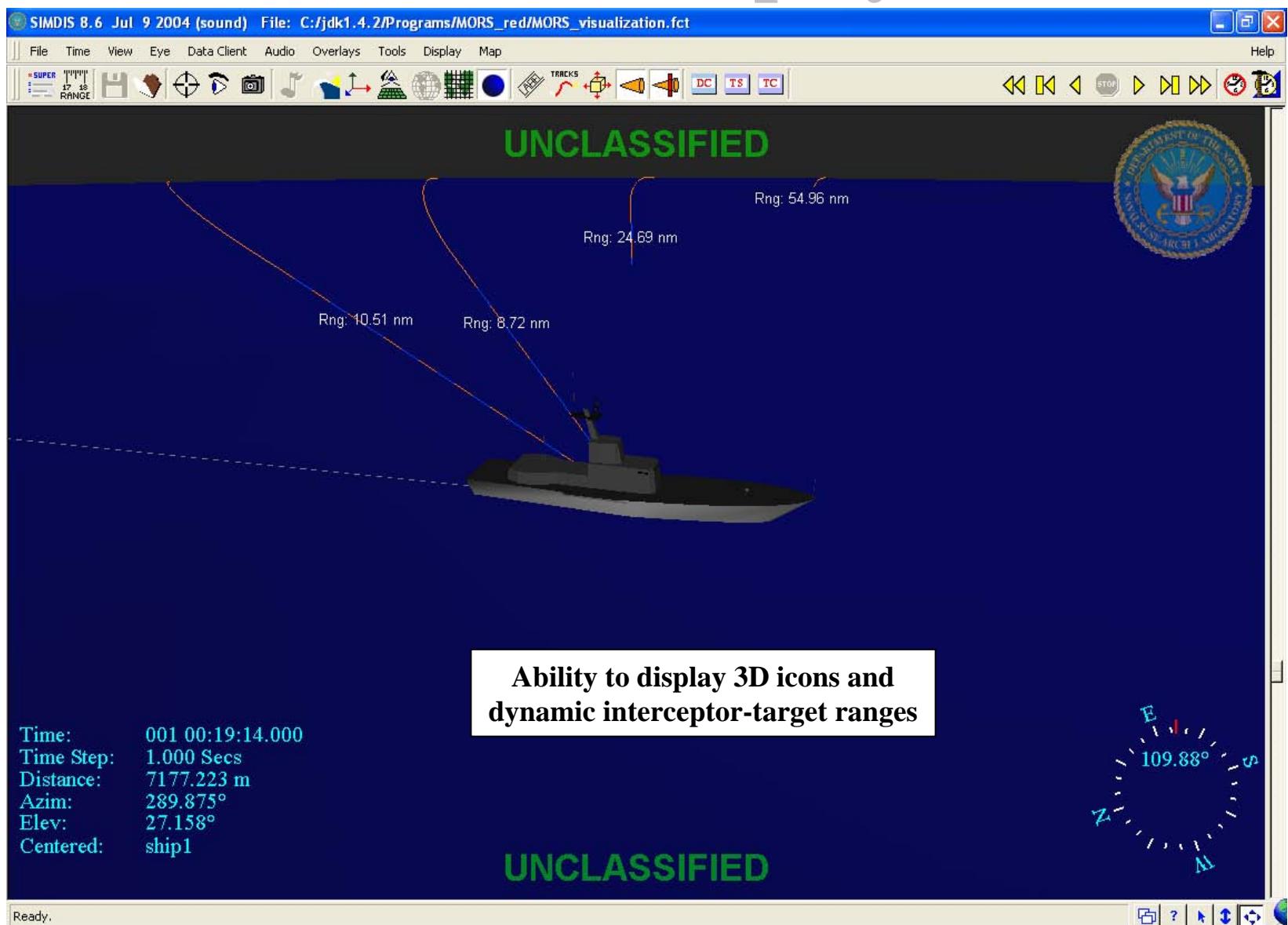
Ready.



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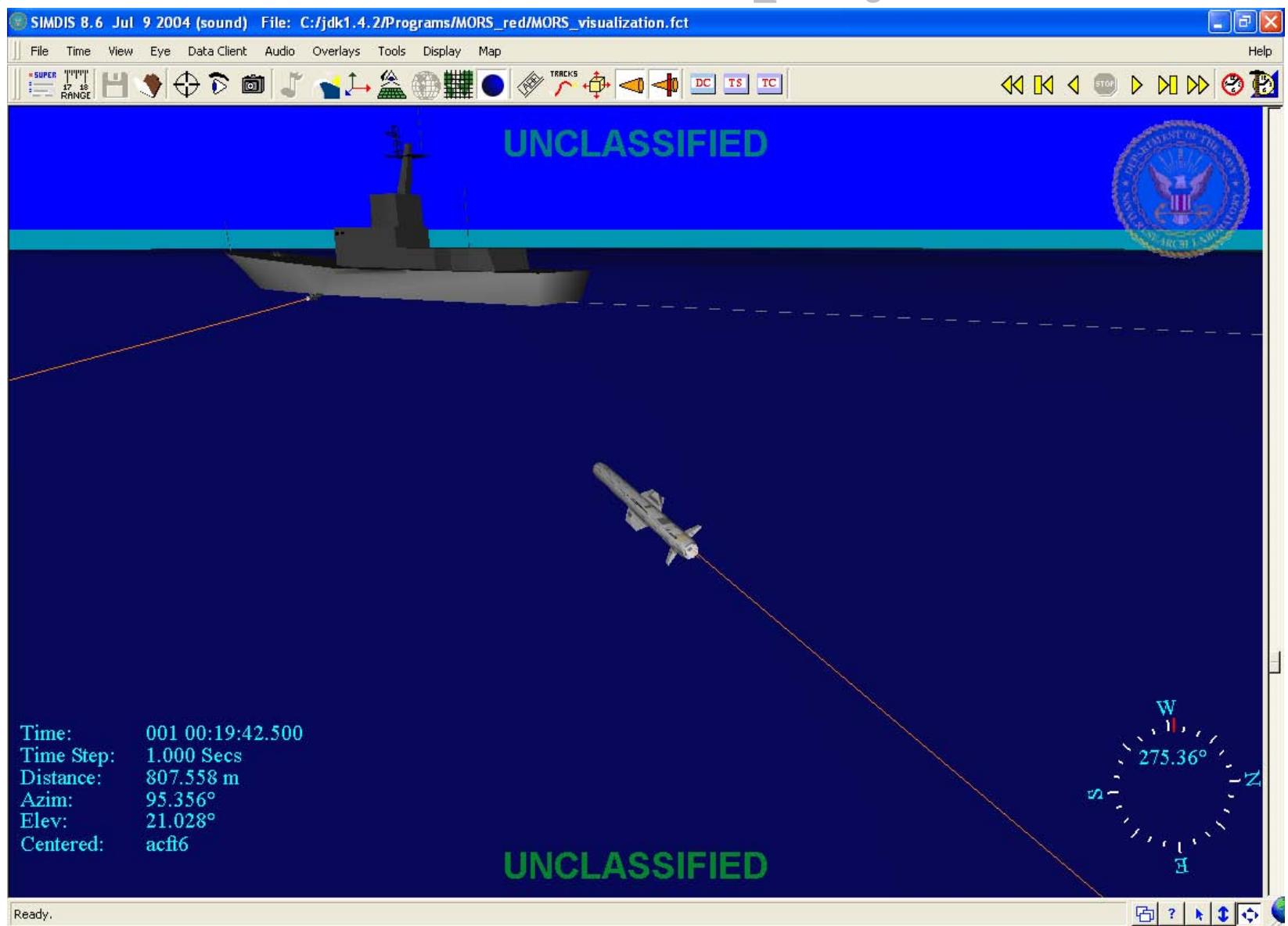


SIMDIS Display





SIMDIS Display



Time: 001 00:19:42.500
Time Step: 1.000 Secs
Distance: 807.558 m
Azim: 95.356°
Elev: 21.028°
Centered: acfb6

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Ready.

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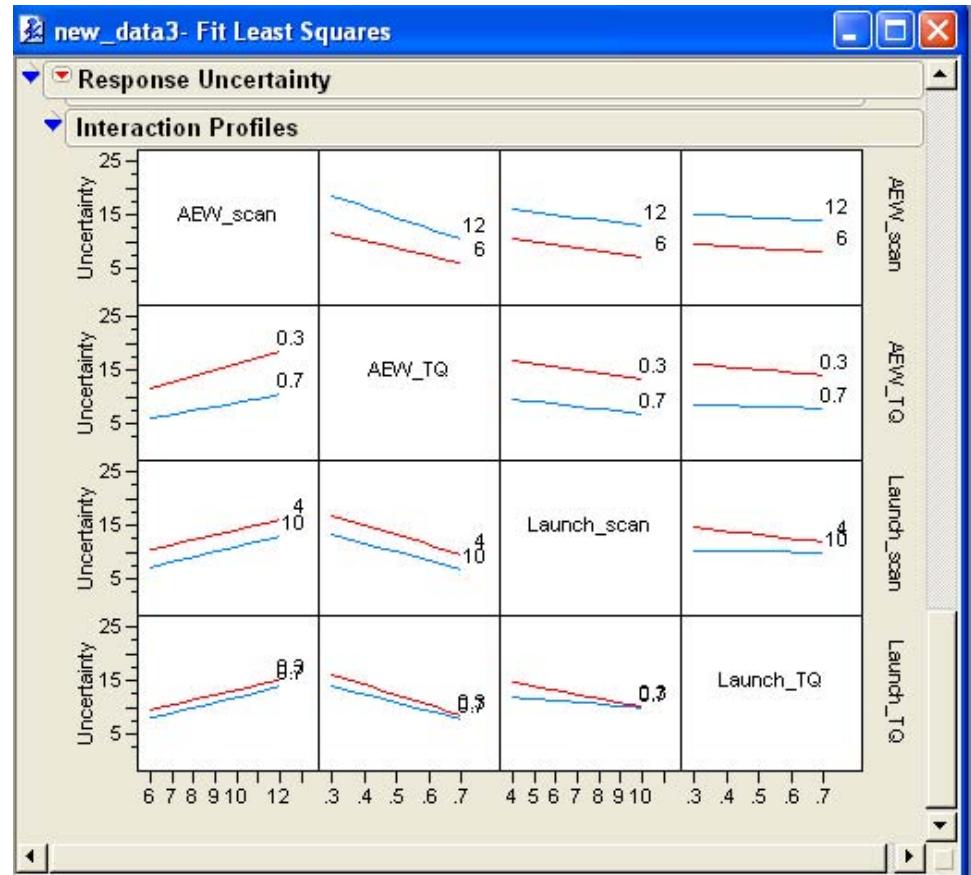
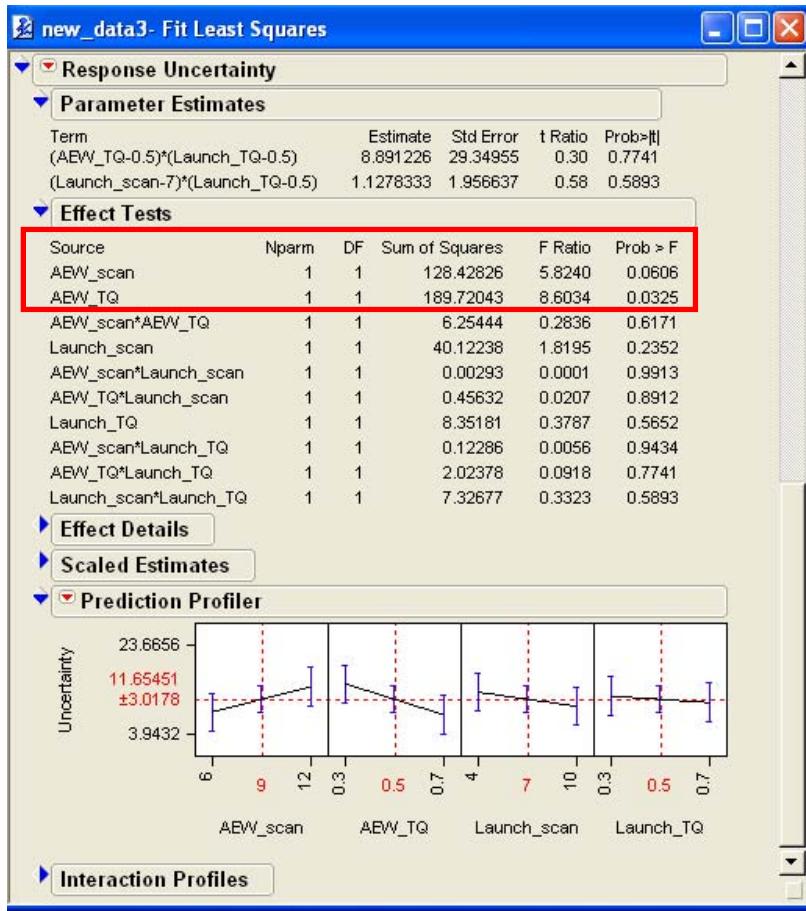


SUW Run Analysis using SAS JMP Software

- SAS JMP may be utilized to show a dependency of the response to several scenario variables
- Through the use of statistical methods, the significant variables or interactions between multiple variables that may be discovered for further analysis



SUW Run Analysis Using JMP



This example shows that the surveillance scan rate and “tracker quality” (probability of detect and how much “uncertainty penalty” is reduced with each successful detection) are most significant factors. Little interaction between cross products.

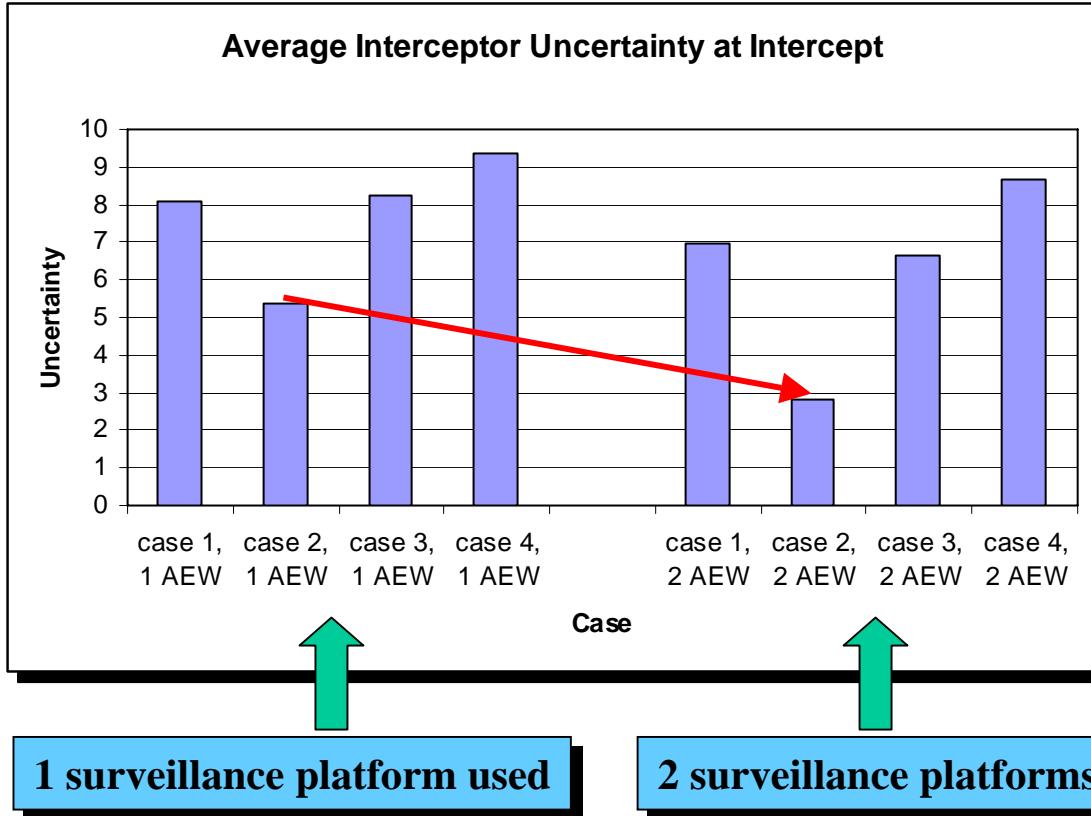


SUW Run Analysis of # of Surveillance Platforms

- Test hypothesis of adding two surveillance to the scenario
- Examine the “uncertainty penalty” at intercept
- Quantify this improvement
- This improvement is also dependent on the quality of additional surveillance
 - If you add a poor platform to the mix, it may get worse



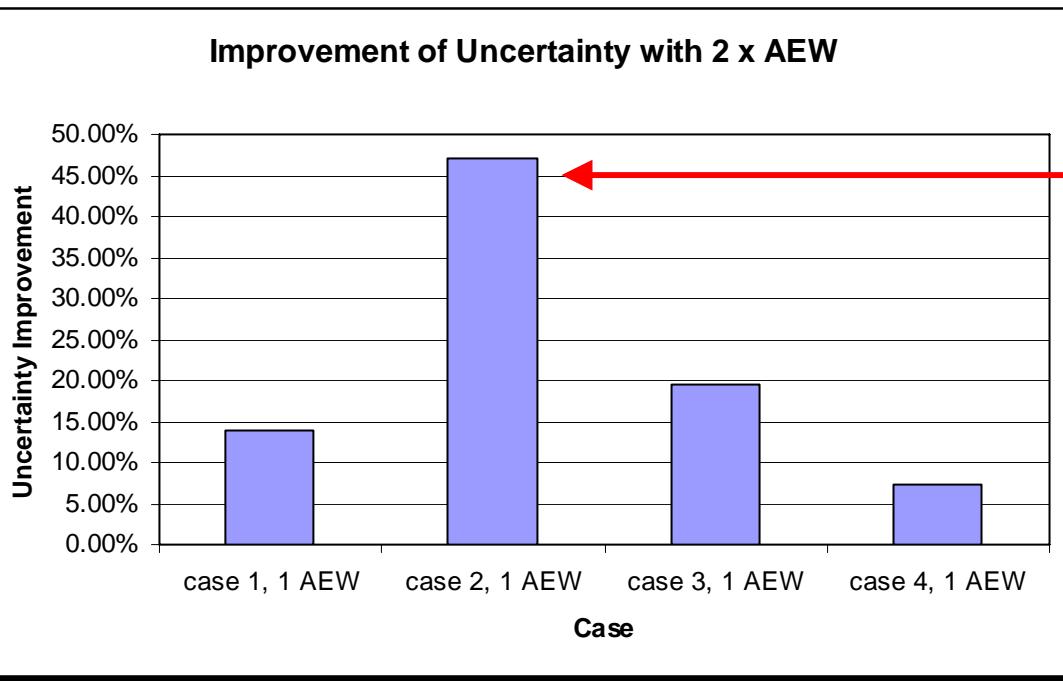
Surveillance Assets Utility for SUW Scenario



The average “uncertainty penalty” shows a decrease when two surveillance platforms are used within the same case



Surveillance Utility Quantification for SUW Scenario



	Scan rates	Track Quality
case 1	good scan	low TQ
case 2	good scan	good TQ
case 3	bad scan	good TQ
case 4	bad scan	low TQ

Good scan rate is half the revisit time over a bad scan rate

Good TQ reduces “uncertainty penalty” double over a bad TQ

Quantify this improvement in “uncertainty penalty” with using two surveillance platforms over one. See notes on the case configurations. It should be intuitive that adding an additional “good” surveillance platform provides more value than a “bad” one. From the graph, you could investigate if a better track quality may indeed be better than increasing the sensor scan rate.



Conclusion

- The objective of this project was to develop a methodology to allow a system of systems analysis to be performed
- There are many different tools that contribute to the overall analysis that may be used
- There are many applications for this methodology to be applied
 - Surface Warfare
 - Undersea Warfare
 - Expeditionary Warfare
- This project is also intended to discover additional questions during the scenario analysis for follow up with increased investigative abilities